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Characteristics of air pollutants at near and far field regions of a national highway located at an industrial complex

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ABSTRACT

This paper presents the characterization of air quality monitored at near field region (NFR) and far field region (FFR) of a national highway located at an industrial complex. The pollutants such as PM_{10}, SO_2 and NO_2 were monitored in two campaigns (11th September to 18th October 2012 and 18th January to 17th February 2013). The 24 h average PM_{10} concentration at NFR and FFR were found to be 86.69 ± 18.56 μg/m^3; 73.16 ± 16.21 μg/m^3 and 89.44 ± 18.69 μg/m^3; 81.91 ± 16.42 μg/m^3, respectively during first and second campaign. In both the campaigns PM_{10}, SO_2 and NO_2 concentration at NFR was higher than FFR. The chemical characterization of PM_{10} at NFR and FFR indicated the abundance of major elements such as Na (NFR = 30% and FFR = 32%), Ca (NFR = 12% and FFR = 14%) and ions namely NO_3^- (NFR = 71% and FFR = 68%) and NH_3^+ (NFR = 15% and FFR = 19%). Further, at FFR, SO_4^{2-} and NO_3^- were found to be 18% and 35% higher than NFR indicating the conversions of SO_2 and NO_2 concentration into secondary particles. The measured SO_2 and NO_2 concentrations were 23 and 21% lower at FFR when compared to NFR confirms the secondary formation.

The CALPUFF, EPA regulatory model was set up to understand the dynamics of air pollutants at the industrial complex. The predicted PM_{10}, SO_2 and NO_2 concentrations at NFR and FFR were found to be 32.31 ± 1.56 μg/m^3 and 31.35 ± 1.27 μg/m^3; 0.37 ± 0.21 μg/m^3 and 0.06 ± 0.04 μg/m^3; 12.83 ± 6.55 μg/m^3 and 4.67 ± 2.77 μg/m^3, respectively. The model showed moderate predictions for PM_{10} (R^2 = 0.44–0.52), SO_2 (R^2 = 0.41–0.51) and NO_2 (R^2 = 0.45–0.61) concentrations.

1. Introduction

Air pollution remains a major environmental problem in the industrial complex despite of various efforts in many developing countries. In the recent past, emissions from the industrial sources are showing decreasing trend, the emissions from vehicles at industrial complex has increased due to increase in vehicle operations and economic growth. Large quantities of chemical compounds are emitted into atmosphere as result of anthropogenic processes. These emissions lead to a complex array of chemical and physical transformations resulting in apparently diverse effects as photochemical air pollution, acid deposition, long-range transport of chemicals and global weather modifications (Atkinson, 1990). Several stringent actions were in developed countries to tackle the air pollution problem in the industrial area. In developing countries, air quality management at the industrial area is still a challenge. A study carried out by the central pollution control board (CPCB) in

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India showed that 43 industrial clusters are having comprehensive environmental pollution index (CEPI) greater than 70 (on a scale of 0–100) and have been identified as critically polluted (CPCB, 2009a,b). In industrial complex, motor vehicles also contributes considerable amount of pollution, because most of the industrial areas are connected to national highways for the purpose of quick transport of raw materials and finished products. In general, traffic on these roads is dominated by heavy duty diesel vehicles. Highways having increased heavy duty vehicles traffic showed elevated particle matter concentrations (Ntziachristos et al., 2007). At present, chemical characterization of PM at industrial area is scanty. The chemical composition at near field and far filed regions and their associations with different emissions sources at near filed and far are not well understood. The information on PM chemical characterization is important to study the effects on human health and surrounding environment.

Dispersion models are widely used to understand the dynamics of air pollutants in near and far field regions. But most of the dispersion models (AERMOD, ADMS, ISCST3, CALINE4, etc.) often assume steady state, straight-line transport of pollutants in time and space. In a complex terrain, this assumption is inappropriate where the wind field is inhomogeneous. The U.S. Environmental Protection Agency (USEPA) has recommended CALPUFF Lagrangian puff model (Earth Tech, Concord, MA) for long range transport modeling (USEPA, 2000), because of its ability to handle complex three-dimensional wind fields. CALPUFF model characteristics include, the capability to treat time-varying point, area, volume and buoyant line sources; suitability for modeling domains from tens of meters to hundreds of kilometers from a source or source complex; predictions for averaging times ranging from one-hour to one year; applicability for inert pollutants and those subject to linear removal and chemical conversion mechanisms; and applicability for rough or complex terrain situations and overwater scenarios (USEPA, 1998). According to USEPA, the CALPUFF may be considered for near field (less than 50 km) regulatory applications when assumptions of steady state straight-line transport in time and space are inappropriate (USEPA, 2008). Near field applications of CALPUFF has received little attention, especially in settings with complex terrain and wind.

In the present study, an attempt was made to characterize the air pollutants at near field region (NFR) and far field region (FFR) of a national highway passing through an industrial complex. The dispersion of criteria pollutants emitted from the industrial complex was also investigated.

2. Methodology

2.1. Study area

The study area-Sriperumbudur (latitude 12.9700°N and longitude 79.9500°E) is in the state of Tamil Nadu, India, and located 40 km west south-west of Chennai city. Sriperumbudur is strategically placed on the Chennai-Bangalore national highway four (NH4). Physiographically, the study area terrain is complex and can be classified into plain land with low-lying hills. The general elevation of the study area ranges from 20 to 140 m above mean sea level (MSL). The elevation contour indicates the area is sloping towards east. Climate of the study area is semi-arid. Wind direction is mostly southwest, west and northwest with an average speed of 7 kmph. The temperature throughout the year is ranging from 37.5 to 20.5 °C and relative humidity is from 60 to 74%. The study area receives good amount of rainfall during northeast monsoon.

There are more than 50 small and large industrial firms are functioning in the state industries promotion corporation of Tamil Nadu limited (SIPCOT), industrial park at Irrungattukottai, Sriperumbudur. Major industrial companies working in this area are Hyundai Motors, Hindustan Motors, Mitsubishi, BMW, Foxconn, Flextronics, Jabil Green Point, Sanmina, Aspocomp, Nokia and Nokia Siemens, Samsung, Nissan, Ford, Renault, Laird Group Plc, Dell, Mahindra & Mahindra, etc. Hyundai was one of the initial investors when they established their Indian car operations in 1999 in Sriperumbudur. The major contributors of pollution in this area are industries and vehicles. Unlike urban roads, which are having large fraction of light duty vehicles, the Chennai Bangalore national highway has comprised of equal distribution of heavy duty and light duty vehicles. PM_{10}, SO_2 and NO_2 measuring instruments have been setup at distance of 10 m (NFR) and 200 m (FFR) from the centerline of the NH4 (Fig. 1). There are 5 stacks present within a radius of 10 km to the monitoring station.

2.2. Air quality monitoring

Two monitoring campaigns were conducted for the measurement of PM_{10}, SO_2 and NO_2 during 11th September to 18th October 2012 (S1) and 18th January to 17th February 2013 (S2) at both NFR and FFR of Chennai Bangalore national highway. High volume samplers (Envirotech APM 460NL) with gaseous attachment (APM 411TE) were used to measure PM_{10}, SO_2 and NO_2 concentrations. The 24 h average PM_{10} mass was collected on glass microfiber filters (Nupore Filtration Systems Private Limited, India) of size 20.3×25.4 cm with an airflow rate of 1.1 m^3/min. About 38 samples were collected per campaign by covering all days of the week to give a fair representation. The instruments were kept at a height of 1.5 m from the ground level. Glass fiber filters were weighted twice before and after sampling by a microbalance with a sensitivity of ±1 μg. Before weighing filters were equilibrated in a desiccator at room temperature with a relative humidity of 40–50% for 24 h. To reduce gravimetric bias due to filter handling during and after sampling, field and laboratory blank filters were collected and analyzed. Filters were placed in aluminum foil sealed cassette while carrying from the field. From the weight differences and airflow rate, the PM_{10} concentrations (μg/m^3) were determined. Further, the weighed filter papers were preserved in a freezer until further chemical analysis.